

## SELECTION OF FOREST STANDS BY SPRUCE BEETLES DURING OUTBREAKS ON THE KENAI PENINSULA

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The spruce beetle is a major destructive agent of spruce ecosystems throughout North America. Approximately 4 million acres of spruce forests were infested in south-central Alaska from 1980-2000. Past outbreaks in Alaska have been associated with warm, dry summers; contiguous stands of mature, slow-growing spruce; and an accumulation of spruce debris from windthrown trees and right-of-way slash. Widespread loss of spruce stands had major impacts on plant diversity, wildlife habitat, and forest productivity through stand conversion. Resultant fuel loading increased the possibility of catastrophic wildfire, particularly in the urban/wildland interface. For Alaska, the greatest ecosystem impact, however, was a potential long-term change in species composition and plant diversity over extensive portions of spruce forests.

A number of factors contributed to the potential for bark beetle outbreaks but the most important appeared to be stressful environmental conditions under which trees grow. Stress often results from lack of silvicultural management improper timber harvest, wildfire, and soil compaction in recreational areas. High annual temperatures and low accumulations of snow seem to be a contributing factor to beetle survival. Windthrown trees, log decks, and right-of-way slash are the most attractive breeding material for spruce beetles.

Host tree species appear to have some effect on beetle population dynamics. In south-central Alaska, the spruce beetle infests white, Sitka, and Lutz spruce (a hybrid between white and Sitka). Lutz spruce is the most susceptible to attack; whereas, white spruce is most suitable for development of the spruce beetle and is typically associated with faster rates of development and more progeny. Sitka spruce is least susceptible to attack and suitable for beetle development.

Spruce beetle infestations on the Kenai Peninsula started in the early 1970's in stands of Lutz spruce located in cold valley bottoms, high elevations, and north and west aspect slopes. As beetle populations increased in the 1980's and annual temperatures warmed in the 1990's, flatland sites became drier and subsequently infested. Uneven-aged stands of spruce are now stands of mixed tree species.

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WARMING CLIMATE AND SPRUCE BARK BEETLE OUTBREAKS: A 250-YEAR RECORD FROM THE KENAI PENINSULA AND THE KLUANE REGION OF THE YUKON TERRITORY

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Both the Kenai Peninsula and southwestern Yukon Territory have experienced extensive outbreaks of the spruce bark beetle (*Dendroctonus rufipennis* Kirby) during the 1990s. When bark beetles thin a forest canopy, surviving trees grow more rapidly for 60 to 80 years until the canopy re-closes. We used dendrochronology to reconstruct bark beetle outbreak history at 23 Kenai Peninsula sites and at 4 sites near Haines Junction in the Yukon Territory. On the Kenai we found tree-ring evidence of regional canopy-thinning events during the 1810s to 1820s, 1870s to 1880s, 1910s, and 1970s, which we attribute to spruce bark beetle outbreaks. The mean beetle-return-interval was 52 years. Every Kenai stand showed evidence of at least one and as many as five thinning events, whereas only one Yukon stand showed evidence of substantial thinning. For that Yukon stand we have historical documentation of a local 1940s outbreak, as well as standing beetle-scarred trees with death dates from 1934-42. We conclude that regional spruce bark beetle outbreaks have occurred on the Kenai at intervals of 20 to 60 years over the last 250 years. In the Kluane area our tree-ring evidence (starting in the 1600s) suggests that no regional outbreaks occurred prior to the 1930s, but that two regional outbreaks have occurred since the 1930s.

The Kenai outbreaks of the 1970s and 1990s followed runs of unusually warm summers (1967-69, 1987-97, respectively). The Kluane outbreak of the late 1990s followed the warm summers of 1989-95. Meteorological records and tree-ring reconstructions of summer temperatures in the Alaska and the Yukon indicate that the warm summers of the 1990s are one of the longest runs of warm summers in the last 200 years.

## LANDSCAPE ASSESSMENT OF SPRUCE BEETLES IN THE COPPER RIVER BASIN

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Between 1989 – 1998, a widespread epidemic of spruce bark beetles (*Dendrocotonus rufipennis*) occurred in the Copper River Basin, Alaska. Over 100,000 ha were affected within the administrative boundaries of Wrangell-St. Elias National Park and Preserve, Alaska (WRST). Relatively little was known about the effect of spruce bark beetles on the forest composition or landscape in the Copper River Basin. Our approach was to map the existing vegetation and infestation, conduct a forest inventory, and conduct landscape level analyses in a GIS environment of beetle infestation in the park.

A vegetation and infestation map was produced using standard photo interpretation techniques on color-infrared aerial photography at a scale of 1:40,000. Within the 257,000 ha study area the total amount of forested area was 181,000 hectares. All forested stands containing white spruce (pure and mixed) made up 58% of the study area. The remaining landscape consisted of 4,230 ha logged lands (2% of the study area), 25,727 ha pure black spruce forest (10%), 6,957 ha pure deciduous forest (3%), and 27,896 ha of other land cover (11%). Of the forest types containing white spruce, 73,346 ha had greater than 10% of its white spruce killed by spruce beetles, which is 29% of the study area and 49% of the white spruce forest types.

We modeled the risk of infestation at both the stand and landscape level. At the stand-level we found that density of both large and small diameter white spruce trees and deeper organic forest floor layers increased the risk of infestation. North facing slopes appeared to have a lower risk of infestation. At the landscape level, the most important variables in predicting risk of infestation were forest type (white spruce and spruce/mix stands) and tree size (trees larger than 22 cm in diameter). Topographic variables also contributed to the overall accuracy of the model, such as surface roughness, which may indicate areas with glacial moraines or active geomorphic processes.

# **FIRE AND ICE (AND BEETLES): A CASE STUDY OF CLIMATIC CONTROLS ON STAND STRUCTURE IN AN UPLAND WHITE SPRUCE FOREST, KENNICOTT VALLEY, AK**

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At the landscape scale, white spruce forest dynamics are largely dictated by disturbance regimes. Disturbances like wildfire and glaciation vary widely in both time and space, however, responding to local and regional climatic conditions that fluctuate with timescales of decades to centuries. In the Kennicott Valley, a sparsely populated glacial valley in Alaska's Wrangell Mountains, I documented the impact of this variability on stand structure and a contemporary spruce beetle outbreak. Site index, disturbance history, current productivity, and population age structure of white spruce were determined at 26 sites on five landform units. The study area consists of even-age stands initiated by deglaciation (20% of study area), wildfire (13%), and anthropogenic fire (26%), and mixed-age stands that exhibit old-growth characteristics (41%).

The differing disturbance regimes have led to clear differences in both beetle activity and stand structure. The mixed young stands of small-diameter spruce and hardwoods that colonized primary and secondary successional surfaces have not yet suffered any significant spruce beetle mortality, while up to 42% of the standing volume has been killed in mature mixed-age stands. Compared to young successional stands, mixed-age stands also tended to have a more open canopy, a denser alder understory, and reduced recruitment of young white spruce. A demographic model based on age-structure in these mixed-age stands shows that recruitment is too low to maintain current tree density, even in the absence of spruce beetle mortality. These results suggest that in the absence of catastrophic disturbance, upland white spruce stands are gradually converted to spruce-alder woodland, a process hastened by the current spruce beetle epidemic. This scenario, played out in a patchy periglacial landscape that minimizes wildfire but episodically bulldozes forests with Little Ice Age glacial advances, contrasts strongly with the dynamics of better-studied forests elsewhere in Alaska. (PAPER)

## SPATIAL AND TEMPORAL PATTERNS OF SPRUCE BEETLE OUTBREAKS IN ALASKA: RESULTS FROM AERIAL DETECTION SURVEYS AND GIS, 1970-1993

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Spruce beetle (*Dendroctonus rufipennis*) activity has occurred over much of the mature spruce (*Picea spp.*) forest component of Alaska since a major infestation was first studied in the upper Copper River region in the early 1920's. Until the mid-1970's, periodic spruce beetle outbreaks occurred primarily in areas of mature and over-mature white spruce (*P. glauca*) that had experienced a significant disturbance event (stem breakage from wind, snow damage, flooding, avalanche, etc.), favoring dramatic increases in beetle populations from natural (endemic) levels to more "unnatural" (epidemic) proportions.

With the exception of the 1920's "Copper River" outbreak, observed spruce beetle activity did not amount to more than 20,000-50,000 acres of new beetle activity statewide during the "early years" of systematic U.S. Forest Service (USFS) bark beetle surveys across Alaska, until about the early 1970's. The earliest forest health assessments by the USFS (and pre-statehood federal entomologists) across Alaska were primarily ground surveys that were documented from cooperator reports, usually tied to a site visit and a forest health report prepared for the requesting landowner. In addition, consistent surveys of spruce beetle activity were generally more limited to localized ground surveys during these early years until USFS incorporated more extensive surveys using low-level aircraft to complete its required annual forest health assessments across the vast, mostly roadless expanse of Alaska's 129 million acres of productive forest lands. Much of the earlier, periodic bark beetle survey data is archived into a Geographic Information System (GIS) database by the Alaska Division of Forestry which has been used to reconstruct the patterns of spruce beetle activity from the early period of USFS forest damage assessments, and is updated annually.

The time patterns and extent of several spruce beetle outbreaks in Alaska from the early 1970's to the present are explained using results from 25 years of annual cooperative USFS & State of Alaska aerial surveys and DNR's archived GIS database of forest damage. Early bark beetle patterns are described although Alaska spruce beetle activity is demonstrated to have increased significantly in frequency and severity of outbreaks over just the last 35 years. Emphasis will be given to the 15+-year Kenai Peninsula beetle epidemic that peaked in 1996. Results from another outbreak in the Copper River region will be described as well as the general pattern of beetle activity that has been documented by aerial assessments and GIS information across Alaska since 1970. [Oral presentation]

## EFFECTS OF A SPRUCE BEETLE OUTBREAK AND FIRE ON LUTZ SPRUCE IN ALASKA

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In one area of the Chugach National Forest, 51% of the Lutz spruce, or nearly 90% of the commercial stand volume was killed by spruce beetles (*Dendroctonus rufipennis*) during a 16-yr period. Species composition remained essentially the same after the outbreak. As of 1991, forest structure changed with decreased tree density, and species richness declined significantly on the unburned, spruce beetle-effected plots. Reduction in plant diversity was probably a result of the significant increase, and competitive advantage, of blue-joint grass. Ground vegetation plots were re-visited in 1996. Blue-joint reed grass cover had significantly been reduced. This supports previous observations that blue-joint vigor is reduced as nutrients become immobilized in organic matter and canopy cover increases. Spruce in-growth was found on 64% and 6% of unburned and burned plots, respectively. Birch seedlings were found on more burned plots than unburned (38% vs. 7%), reflecting species composition prior to the burn. [Oral presentation]

## BROAD-SCALE SPRUCE FOREST CHANGE, KENAI PENINSULA, 1987-2000.

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During the past fifteen years spruce forests of Alaska's Kenai Peninsula have undergone dramatic changes resulting from widespread spruce bark beetle infestation. In 1987 and again in 2000, the Pacific Northwest Station's Forest Inventory and Analysis (PNW-FIA) program conducted initial and remeasurement inventories to assess broad-scale impacts of this infestation.

Changes in productive forest area, volume, growth and mortality, spruce seedling reproduction, and down woody material are presented. White and Sitka spruce sawtimber area declined 65 percent, cubic volume on productive forest declined by 50 percent, and annual average mortality exceeded average annual growth by 2 to 1. Regeneration of white and Sitka spruce, however, is not dramatically different from 1987. The number of plots where seedling stocking remained at previous levels or improved exceeds the number of locations where seedling stocking declined. Notable for fire management is widespread increases in almost all fuels classes and heights along with reductions in moss depths. (PAPER).

# VEGETATION CHANGE AND FOREST REGENERATION ON THE KENAI PENINSULA FOLLOWING A SPRUCE BARK BEETLE OUTBREAK, 1987-2000

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Forests of the Kenai Peninsula have changed dramatically over the past fifteen years following widespread spruce bark beetle infestation. In 1987 and again in 2000, the Pacific Northwest Station's Forest Inventory and Analysis program conducted initial and remeasurement inventories to assess broad-scale impacts of this infestation.

Analysis of vegetation composition was conducted to determine the overall pattern of vegetation change as a result of the infestation and to evaluate the effect of vegetation change on forest regeneration. Specifically, the effect of bluejoint reedgrass (*Calamagrostis canadensis*) on white spruce (*Picea glauca*) and Sitka spruce (*Picea sitchensis*) regeneration was assessed.

Changes in vegetation composition were evaluated with indirect gradient analysis using non-metric multidimensional scaling. Forests of the southern Kenai Lowlands showed the most marked change in composition indicated by relatively large distances between the two readings in the ordination space. Change in composition was characterized by high spruce mortality, increases in bluejoint and fireweed (*Chamerion angustifolium*) and was consistent with the environmental gradient representing disturbance. Spruce-mountain hemlock (*Tsuga mertensiana*) forests of the Kenai Mountains showed a directional change characterized by increases in mountain hemlock, tall blueberry (*Vaccinium ovalifolium*), and rusty mensiezia (*Mensiezia ferruginea*). Coastal forests and mid- to northern Kenai Lowlands did not show consistent directional changes in vegetation composition.

On the southern Kenai Lowlands, bluejoint increased by at least 10% on 12 out of 33 plots, but did not increase markedly elsewhere on the Peninsula. Regeneration of white and Sitka spruce did not change dramatically across the study area from 1987 to 2000. (PAPER)



## A SYNTHESIS OF ENRI FINDINGS FROM 5 YEARS OF STUDY OF THE SPRUCE BARK BEETLE ON THE KENAI PENINSULA.

Jim LaBau

The University of Alaska's Environment and Natural Resources Institute (ENRI) collected and analyzed data on the spruce bark beetle on the Kenai Peninsula on two concurrent studies since 1997. Several reports and papers have been presented on the results of the analysis, including general forest inventory data, impact on understory, type of mortality most useful to these studies, and status of health of the surviving forest. This paper synthesizes the results from those various studies.

## CHANGES IN FOREST STRUCTURE FROM AN OUTBREAK IN THE COPPER RIVER BASIN

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In Wrangell-St Elias National Park and Preserve 136 forest inventory plots were established to assess differences in forest vegetation structure and composition and to develop a predictive model of vegetation change. Spruce beetles had a substantial immediate influence on forest structure in terms of canopy and basal area reduction, and changes in forest species composition. White spruce canopy cover and basal area of large trees (> 15 cm DBH) were reduced linearly as infestation increased, while black spruce were infrequently hit by spruce beetle. Changes in the cover and composition of understory vegetation and accumulation of woody debris were less evident in this study. In stands with high mortality due to spruce beetles (>60% mortality) seedling densities were low (418 seedlings/ha) and may result in a longer forest regeneration time without an increase in seedling germination and survival. Low seedling density also raises questions about reforestation of the 4,230 ha of harvested forest in the Chitina Valley.

A model to predict vegetation changes due to spruce beetles was developed and applied to the vegetation map completed as part of this study. Changes in forest stands were based primarily on the presence of white spruce. We predicted that under low or moderate levels of infestation, mixed white spruce forests with black spruce or deciduous species would lose their white spruce component. Under moderate levels of infestation, we expect canopy cover in open pure white spruce stands to be reduced to a woodland canopy (10-25% tree cover). Under high levels of infestation, almost all forested types containing white spruce were predicted to change to non-forested (<10% tree cover) vegetation types. Forest stands with low to moderate infestation will probably see a release of the residual trees and, over time, would look similar to how they were prior to the spruce beetle infestation. FRAGSTATS analyses were utilized to assess existing vegetation and predicted vegetation.



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## LUTZ SPRUCE FIRE AND BARK BEETLE DISTURANCE REGIMES ON THE KENAI PENINSULA

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The Kenai Peninsula has a low incidence of lightning and humans have caused virtually all historically documented fires. Nevertheless, on a scale of decades to centuries, fire has been an important process on the landscape, second only to spruce bark beetles. For Paradox Lake we have a 14,000-year post-glacial record of charcoal abundance in a 9-meter lake sediment core which shows that fire was most abundant during the warm and dry Hypsithermal tundra period, peaking ~10,000 years ago with ~12 fire events/1000 years. When white and black spruce arrived 8000 years ago, fire frequency declined to 8-10 events/1000 years. For last 3000 years the fire frequency has been ~5 fire events/1000 years, implying a mean-fire-return interval of 200 years.

We used 121 radiocarbon-dated soil charcoal samples to date fires in upland spruce-dominated forests from Anchor Point to Nikiski. The oldest sample dated to 5030 years. The mean fire-return-interval was 860 years, and the mean time-since-fire was 640 years.

Our dendrochronology studies of spruce bark beetle outbreaks at 23 sites show that over the last 250-300 years (for which we have dateable tree-rings), spruce bark beetles have thinned the forests with a mean beetle-return-interval of 52 years. Spruce bark beetle outbreaks are thus the dominant form of disturbance driving the upland forest cycle on the Kenai Peninsula.

Our estimates of fire and beetle return intervals imply that in the past, one fire occurred for every 16.5 spruce bark beetle outbreaks in these forests. Nevertheless, a run of warm summers since 1987 has created a spruce bark beetle outbreak of unprecedented scale, and at least two fires with high rates of spread in recently beetle-killed timber have occurred. This suggests that with a future warmer climate and increasing human use of the landscape, fire and beetle kill may well be more closely associated than in the past.

## BLACK SPRUCE FIRE HISTORY OF THE KENAI LOWLANDS, KENAI NATIONAL WILDLIFE REFUGE, ALASKA.

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Fire is an integral part of the ecology of lowland black spruce forests on the Kenai Peninsula, however the history of fire in these forests is largely unknown. A detailed tree-ring based fire history study was undertaken to determine the history of fire in Kenai Peninsula lowland black spruce forests. Utilizing techniques of dendrochronology, age class analysis of living and dead trees, fire scars, and outer-ring death dates of fire-killed trees (burn poles) were used to date and map twelve (12) fires. Fire dates ranged from 1708 to 1898 with fire return intervals ranging from 18 to 166 (S.D. 46) years and a mean fire return interval (MFRI) of 82 years. Analysis of the temporal pattern of fire events revealed a gap in fire occurrence between 1762 and 1828, while nine of the 12 fires occurred between 1828 and 1898.

The gap in fire occurrence coincides with the onset of the coldest time period of Little Ice Age (the 19<sup>th</sup> century cold period) and to a period of very low fire activity in western Canada, the western and southwestern United States, northern Quebec, and Sweden. This may be an indication of some larger Northern Hemispheric climatic shift at this time. The increase in number and frequency of fires after 1828 is attributed to, in part, an increase in human presence on the Kenai Peninsula and climatic conditions more conducive to fire ignition and spread. (PAPER).

# MODELING FOREST SUCCESSION AND DISTURBANCE REGIMES ON THE KENAI PENINSULA, ALASKA, USING THE FIRE EFFECTS TRADEOFF MODEL

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A modeling analysis was undertaken to explore the long-term impacts of the white spruce (*Picea glauca* [Moench] Voss) die-back on vegetation cover and wildfire behavior on the Kenai Peninsula, Alaska. During the 1990's a significant portion of the white spruce stands were killed by infestation with the spruce bark beetle. The presence of extensive areas of dead white spruce can have significant impacts on the future distribution of vegetation types. Moreover, increased dead and down woody debris on the forest floor is believed to increase the risk of large-scale wildfires. Vegetation and wildfire dynamics were simulated over a 100-year period using the Fire Effects Tradeoff Model (FETM). A geographic information system (GIS)-based vegetation coverage totaling approximately 1 million acres was used to describe the initial vegetation distribution. Vegetation types were classified by species, successional stage and stand density. Simulations were run for two analysis areas, the developed coastal strip (Critical Fire Management Zone), and the interior of the peninsula (Full, Modified and Limited Fire Management Zones). The fire frequencies (mostly human caused) in the coastal and interior zones were ~11 and 0.8 fire starts per 10<sup>5</sup> acres per year, respectively. Modeled natural disturbances included succession, browsing by ungulates, spruce bark beetle mortality in white spruce, and wildland fire. Forest management practices included in the simulations were: an ecosystem broadcast burn, and salvage logging of white spruce with and without replanting of white spruce. The initial results indicated that application of the various fuel treatments decreased the total wildfire acreage and PM<sub>10</sub> emissions in the coastal area, but had little effect in the interior areas. In both areas the white spruce acreage increased during the first 20 years due to fuel treatments, but then gradually declined. The acres of grass and hardwood vegetation types increased dramatically over time, as many beetle-killed areas of white spruce do not grow back as white spruce unless planting occurs.

## CHANGES IN THE QUALITY OF FIRE FUELS OVER TIME FOLLOWING AN OUTBREAK ON THE KENAI PENINSULA

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This study examined the decay-class specific densities and decomposition rates of decaying Lutz spruce (*Picea x lutzii* Little) on the Chugach National Forest. Although, the majority of trees were killed by spruce bark beetle (*Dendroctonus rufipennis* Kirby), we also examined trees killed by fire, flooding, and wind. We employed the chronosequence method, dating snags and logs using Forest Service records and dendrochronological methods to determine when tree mortality occurred. A range of decomposition stages and a range of environmental conditions were sampled to determine a representative average rate of decomposition. Samples were removed from boles or stems of snags, logs, and live trees and the density of bark and wood was determined. The mean wood densities of logs for decay classes one through five ranged between 0.387 g cm<sup>-3</sup> and 0.105 g cm<sup>-3</sup>, respectively. This change takes approximately 70 years. For snags, mean wood densities for decay classes one through three ranged between 0.387 g cm<sup>-3</sup> and 0.421 g cm<sup>-3</sup>, respectively, indicating minor changes as snags stand. The average decomposition rate of snag and log wood combined was 0.018 year<sup>-1</sup>, with decomposition being slower in the early years and faster in the later years. The long-term decomposition rate constant was 0.019 year<sup>-1</sup> for log bark and wood and close to zero for snag bark and wood indicating little or no decomposition for snag wood. We hypothesize that these differences in decomposition rates are to be caused by excessive drying in snags.

**Oral presentation**

## FIRE RESEARCH IN ALASKA

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The Fire and Environmental Research Applications Team (FERA) of the Pacific Northwest Research Station has been involved in fire research in Alaska since 1990. In response to the needs of land managers FERA has directed its fire research into three major thrusts including 1) develop methods to assess fuels; 2) develop a system to characterize fuels at all scales; and 3) develop models to estimate fuel consumption and smoke production from wildland fires. The Pacific Northwest Research Station, Department of the Interior, Joint Fire Science Program, and National Fire Plan, have supported these projects. This abstract briefly describes the ongoing research, outcomes, and product development directly related to the fire research in Alaska initiated by FERA.

### Fuel Assessment

Knowing the amount of biomass and other fuel characteristics across a landscape is increasingly important to fire managers as new fuel and fire management decision support systems come on line. Throughout the country, land managers use the photo series as a simple, easy method for quantifying existing fuel characteristics. However, since there were no photo series available for boreal forest fuelbed types of interior Alaska, the Department of the Interior and Joint Fire Science Program supported research to develop a photo series for the black spruce, white spruce, and hardwood types in Alaska. Volume I, black and white spruce photo series, and volume IIA, hardwood and spruce, are complete and may be purchased from the National Interagency Fire Center Publication Management System in Boise, Idaho.

### Fuel Characteristics

Ongoing development of more sophisticated fire models and the implementation of large landscape assessments has demonstrated the need for a comprehensive system of fuelbed classification that more accurately captures the structural complexity and geographical diversity of fuelbeds. FERA is developing a national Fuel Characteristic Classification System (FCCS) to meet this need. The system will offer consistently organized fuels data along with numerical inputs to fire behavior, fire effects, and dynamic vegetation models. The FCCS is supported by a large data library that warehouses fuels information including biomass equations, physiognomic features, and physical parameters. This information was compiled from published and unpublished literature, photo series datasets, and expert opinion from across the United States. A total of 50 fuelbed prototypes have been developed for the Alaska boreal forest and tundra types with several hundred additional prototypes currently under development.

### Fuel Consumption and Emissions Production

The Joint Fire Science Program funded a 3-year study to measure and model forest floor consumption and sample flaming and smoldering emissions during wildfire and prescribed fires in the boreal forests of Alaska. During the summer of 2003, fuel consumption was measured at several wildland fires and prescribed fires. In addition, several hundred forest floor "moss and duff plugs" were collected and transported to the Missoula Fire Lab, burned, and emissions sampled under various moisture and frozen layer conditions. This data in combination with earlier fuel consumption data gathered from wildland fires near Tok, Mystery Creek (Kenai Peninsula), Palmer, and Fairbanks will be used to develop a robust set of fuel consumption models and improve emission factors for implementation into the Consume 3.0 model.

PAPER

## RESPONSE OF RED-BACKED VOLES TO SPRUCE BEETLE INFESTATIONS IN THE COPPER RIVER BASIN, ALASKA

Thomas J. McDonough\*<sup>1</sup> and Eric Rexstad<sup>2</sup>

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The impact of habitat changes caused by forest insect epidemics on small mammals is largely unknown. A mark/recapture effort was conducted on northern red-backed vole (*Clethrionomys rutilus*) populations for 2 field seasons in the Copper River Basin, Alaska where recent spruce beetle (*Dendroctonus rufipennis*) infestations were widespread. Estimates of vole abundance, survival, and recruitment were produced in 3 locations that varied in their degree of beetle-induced spruce mortality utilizing the robust design to estimate parameters. There was significantly greater vole abundance on low versus heavily infested sites (1997  $P < 0.01$ , 1998  $P = 0.02$ ), but no differences between low and medium infested sites (1997  $P = 0.47$ , 1998  $P = 0.36$ ) or medium versus heavily infested sites (1997  $P = 0.12$ , 1998  $P = 0.48$ ). Vole survival differences were not found across the 3 locations with varied beetle-induced spruce mortality levels, but slight variation on replicate grids within each area was detected using habitat variables as group covariates. Percent beetle-killed spruce used as a group covariate showed a slight decrease in vole survival with greater spruce mortality. Vole recruitment was only estimated in the fall of 1997 and showed a larger contribution from both immigration and *in situ* reproduction in the low infestation area than in the medium and heavy infestation sites. Although our data did show voles responded negatively to beetle-killed forest impacts as measured by abundance and recruitment, there was not detectable variation across all 3 levels of beetle infestation and no large survival impacts. The response of voles to the habitat disturbance in the Copper Basin 7-10 years after the initial beetle infestation was moderate. (POSTER)

SURVEY OF SONGBIRDS DURING A SPRUCE BEETLE (*DENDROCTONUS RUFIPENNIS*) OUTBREAK ON THE KENAI PENINSULA, ALASKA

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A spruce beetle (*Dendroctonus rufipennis*) epidemic in southcentral Alaska has caused extensive mortality to spruce trees and a change in forest stand structure. Because a change in forest vegetation can influence composition and abundance of forest birds, we attempted to assess the type and magnitude of change in bird populations within 2 forest stands on the Kenai Peninsula that were undergoing differing levels of spruce beetle infestation. In addition, we compared bird populations occupying a salvage-logged forest site with those in the other forest stands. During our survey period (1994 to 1998), species composition and abundance of land birds differed across the sampled forest stands. Avian species diversity and richness was greatest in the early successional stage of the logged forest and least in the heavily infested forest stand where many spruce trees killed by the spruce beetle had fallen to the ground. As predicted, ground nesting and foraging bird species increased where trees had fallen or were removed. Conversely, the abundance of mature conifer forest birds, such as Townsend's warblers (*Dendroica townsendi*) and ruby-crowned kinglets (*Regulus calendula*) decreased in those forest stands that lost overstory structure. Townsend's warblers declined in abundance through time, potentially due to the loss of mature conifers for nest sites. Bird abundance was greater within the lightly infested stand in 1996, possibly due to immigration of birds from less suitable habitats. Because forest stand characteristics will continue to change through time following the spruce beetle epidemic, we suggest that songbird communities will also remain dynamic in response to changing habitats.



LOGGING OF WHITE SPRUCE FORESTS IN ALASKA: IMPLICATIONS FOR  
NORTHERN RED-BACKED VOLES (*CLETHRIONOMYS RUTILUS*)

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We investigated population changes in northern red-backed voles (*Clethrionomys rutilus*) during the spruce beetle infestation on Chugach National Forest lands on the Kenai Peninsula, and monitored the population changes through the subsequent forest management practices used to reduce the risk of catastrophic forest fire. We quantified northern red-backed vole population changes following timber harvest and hypothesized that microtine abundance would change through time in both natural and managed stands. We tested predictions that: (1) the spruce beetle infestation would have a positive effect on northern red-backed vole populations due to increased food production in open canopy forest and an increase in the accumulation of downed logs used for cover and (2) timber harvest would have a negative effect on northern red-backed vole populations due to their association with mature forests

We documented an apparent peak and fall in northern red-backed vole abundance during this 10-year monitoring study. But rather than the 3-5 year cycle reported by other researchers, the vole cycle in our study appeared to be more protracted. Timber harvest further depressed vole populations in our study area, but eight years post-harvest, population levels appear to converge across logged and unlogged sites. Comparison of vegetation data between unharvested and harvested sites indicate an increase in overstory cover from tall shrubs and increase in recruitment of newly dead, downed material to the forest floor at the unharvested sites compared to the harvested sites. Cover provided by the tall shrub overstory as well as continuous, downed woody material on the forest floor may have provided a more stable, high quality habitat for red-backed voles as they progressed through their cyclic low phase.

## NESTING ECOLOGY OF BOREAL FOREST BIRDS FOLLOWING A MASSIVE OUTBREAK OF SPRUCE BEETLES IN THE COPPER RIVER BASIN, ALASKA

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We examined the nesting ecology of yellow-rumped warblers (*Dendroica coronata*) and dark-eyed juncos (*Junco hyemalis*) from 1997–1998 among forests with different levels of spruce (*Picea* sp.) mortality following a large outbreak of spruce beetles (*Dendroctonus rufipennis*) in the Copper River Basin, Alaska. Both warblers and juncos maintained viable rates of nest success (55% and 45% of nests fledging young respectively) under heavy disturbance. Yellow-rumped warblers nested exclusively in spruce but nest success did not vary with disturbance, presumably because birds altered their use of habitats. As disturbance increased, warblers switched from selecting nesting areas with high densities of medium-diameter white spruce (*Picea glauca*) to areas with high densities of beetle-killed spruce. Warblers also switched from nesting in live spruce (80% of nests in areas with low-to-moderate disturbance) to beetle-killed spruce (60% of nests in areas with high disturbance) as levels of disturbance increased; however, nest survival was equivalent between nests in live and dead spruce. In contrast, most dark-eyed junco nests in forests with low disturbance were lost to predators. As a result, nest success of juncos breeding in forests with low disturbance (4% success) was lower than that of juncos nesting in moderate-to-heavily disturbed stands (45% success), possibly due to relatively high densities of red squirrels (*Tamiasciurus hudsonicus*). Six of 13 species of spruce-nesting birds nested in beetle-killed spruce. Because dead spruce may remain standing for 50 or more years in the Copper River Basin, salvage logging of beetle-killed conifers will eliminate viable nesting sites in the region and may disrupt the ability of spruce-nesting birds to sustain breeding populations until natural reforestation occurs.

## FORAGING ECOLOGY OF YELLOW-RUMPED WARBLERS IN RESPONSE TO AN OUTBREAK OF SPRUCE BEETLES

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Many consider northern latitudes to provide prime habitat for migratory birds because of the ample food-resources (arthropods) and lesser competition than in the south. But what happens to this food source when white spruce, a prominent tree species in Interior Alaska, is drastically reduced in the environment? To address this question, we quantified foraging behaviors of Yellow-rumped Warblers (*Dendroica coronata*) in commonly used tree species (by breeding period) within stands of either low-moderate (<40%) or high (>40%) spruce mortality, resulting from a massive spruce bark beetle infestation. We also compared arthropod densities (by mass) among tree species by sampling branch clippings. In plots with low-moderate spruce mortality Yellow-rumped Warblers foraged most often in quaking aspen (28%), live white spruce (28%), and willow (25%), and in plots with high mortality they foraged most in quaking aspen (32%), dead white spruce (24%) and live white spruce (18%). An examination of tree species use and availability revealed that Yellow-rumped Warblers exercise selection for quaking aspen for foraging. Results from branch clippings showed that arthropod densities varied significantly among tree species, between breeding periods (incubation and nestling) and between levels of stand mortality. Conversely, prey attack rate (foraging success) was comparable among the most commonly used tree species, breeding periods and levels of stand mortality. Our findings suggest that the loss of live white spruce does not diminish the ability of Yellow-rumped Warblers to obtain food, and in fact, dead white spruce serves as an important foraging substrate despite the relatively few arthropods associated with it. Yellow-rumped Warblers are highly plastic foragers, using trees species that are either very abundant, provide the greatest arthropod densities or both. Future studies should examine the effects of heavy spruce mortality on a white-spruce specialist, such as Townsend's Warbler (*Dendroica townsendi*).

PAPER

KENAI PENINSULA BROWN BEARS (*URSUS ARCTOS*): RECENT RESEARCH INTO POPULATION STRUCTURE AND HIGHWAY CROSSINGS, AND IMPLICATIONS FOR POPULATION STATUS.

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Natural or human caused landscape scale changes may affect brown bear (*Ursus arctos*) populations. Habitat availability can be reduced, animals may be displaced, natural movement patterns can be disrupted, and population gene flow can be modified. We report research documenting both the current genetic structure of the Kenai brown bear population and research examining movements of bears crossing highways. We summarize the research results in the context of management issues on the population status of Kenai brown bears. Data from 20 bi-parentally inherited microsatellites and from nucleotide sequences of maternally inherited mitochondrial DNA control region were used to determine the genetic variation of Kenai Peninsula brown bear. Nuclear genetic variation was found to be similar to other peninsular brown bear populations in Alaska and no significant inbreeding or genetic signature of a demographic bottleneck were detected. However Kenai brown bears have a lower mitochondrial DNA haplotypic diversity as compared to other brown bear populations.

Bear location data from radiotelemetry studies were used to determine the spatial and temporal distribution of brown bear crossings of the Sterling and Seward Highways. An information theoretic approach comparing logistic regression models was used to determine if traffic volume, distance to cover across the highway, road density, distance to the closest stream, bear activity level, or time of day influenced bear highway crossing location or timing. Most bears crossed the highway less frequently than expected. While bear highway crossing locations were spatially clustered, no models strongly explained the clustering. Bears were more likely to cross the highway during nighttime. Bear movements were faster and more perpendicular to the highway as bears approached and crossed the highway. (PAPER).

# HOW TO EAT AN ELEPHANT: DEVELOPING EFFECTIVE LOCAL GOVERNMENT RESPONSES TO MASSIVE SUDDEN TREE MORTALITY ON THE KENAI PENINSULA

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The spruce bark beetle (*Dendroctonus rufipennis* Kirby) has caused massive spruce mortality on over 1,500,000 acres within the boundaries of the Kenai Peninsula Borough during the past fifteen years. This spruce bark beetle outbreak killed millions of trees in and around Kenai Peninsula communities and caused the sudden emergence of 200,000 acres of high hazard forest stands within the Wildland-Urban Interface<sup>3</sup> of the Kenai Peninsula.

Public outcry and congressional concern over the increased wildfire hazards on the Kenai Peninsula lead to the establishment of the Kenai Peninsula Borough's Spruce Bark Beetle Mitigation Program in 1999. Since 1999 the Kenai Peninsula Borough (KPB), as the region's local government, has acted as the lead agency for coordinating, developing, and implementing a comprehensive, collaborative spruce bark beetle mitigation effort for the Kenai Peninsula.

This plenary discussion will focus on the process that the KPB Spruce Bark Beetle Mitigation Program has followed to develop effective mitigation responses to a landscape level natural disturbance. Topics will include utilizing current and future hazard/risk assessment technologies, establishing productive multi-party working groups, creating efficient intra-agency procedures, and developing project decision matrixes for prioritizing mitigation efforts. A poster presentation will be prepared for the symposium.

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<sup>3</sup> Wildland-Urban Interface refers to an area or location where a wildfire can potentially ignite homes.

## **The Moose Pass Cooperative Project: A Multi-Agency Approach to Reducing Wildfire Risk**

Elizabeth Bella

The spruce bark beetle epidemic in the Moose Pass area introduced new complexities in fuel reduction strategies due to the mosaic of landownership, the proximity of the Seward Highway, and the temporal need to reduce wildfire risk within the forest and urban interface in this community. The Moose Pass - Crown Point interagency hazardous fuel reduction project, initiated in February 2002, included a variety of cooperators from federal, state, and local agencies. The three main project priorities included protecting lives and property, protecting the Seward highway, and protecting power lines. Project objectives were broken into short term including hazard tree and fuel reduction and fire break construction, and long term including additional targeted fuel reduction in concentrations of dead spruce and reforestation of treated sites. Approximately 800 acres were treated in the accomplishment of short term goals. Long term goals to be completed by 2009 are incorporated in the Seward Ranger District fuel reduction strategy.

## **MANAGING INFESTED FORESTS ON THE KENAI NATIONAL WILDLIFE REFUGE**

**Robin L. West,**

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**ABSTRACT:** Kenai National Wildlife Refuge includes approximately two million acres in the heart of the Kenai Peninsula, a rapidly growing region in Alaska that has been subjected to extensive mortality of mature spruce (*Picea* spp.) forests from bark beetle (*Dendroctonus rufipennis*) infestation during the past several decades. The Refuge is one of 542 in the National Wildlife Refuge System which manages habitats for the primary purpose of wildlife conservation. Over half of the Kenai Refuge is also Congressionally designated Wilderness. The beetle-killed forests in the region have raised questions on forest health and ecology, impact to local economies, and human health and safety risks from wildfire. The Refuge has addressed these concerns through: 1) research to better understand the recurring phenomena of beetle outbreaks, 2) vegetation mapping to assess the extent of the problem and evaluate risks, 3) prescribed fire and mechanical treatment programs to create potential fire breaks and benefit wildlife, and 4) new partnerships and public education and outreach. The Refuge continues to work in a cooperative fashion to evaluate potential problems and solutions on the ongoing beetle infestation issue. These evaluations are based on legal, financial, and biological analyses, but also have social, political, and economic influences.

## VEGETATION CHANGE: A LOOK AT THE KENAI USING THE SIMPPLLE MODEL (SIMULATING PATTERNS AND PROCESSES AT LANDSCAPE SCALES)

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A version of the landscape level simulation system SIMPPLLE has been created for South Central Alaska to be used on the Kenai Peninsula for the Joint Fire Sciences study, "A Risk Based Comparison of Potential Fuel Treatment Trade-off Models." SIMPPLLE is a spatially explicit, stochastic modeling system designed to evaluate vegetation treatments within the context of a dynamic landscape. The system provides for the interaction of insects and diseases with fire processes within the vegetation pattern of a specific landscape. The entire Kenai Peninsula is represented in the model by dividing a vegetation inventory provided by the Kenai Peninsula Borough into 5-acre (plant community) polygons. In order to predict the probability of spruce beetle (*Dendroctonus rufipennis* (Kby.)) activity for each 5 acre polygon we incorporated components of SBexpert, the knowledge-based decision-support system developed by Keith Reynolds and Edward Holsten. The current inventory was backdated to 1970 to create pre-beetle vegetation conditions. Simulation results display the ability of the modeling system to recreate a high level of beetle activity with warmer and drier yearly time steps. The results of the simulations representing future vegetation conditions following the current beetle activity are very dependent upon assumptions made about regeneration of white spruce in stands as mortality was occurring and the level of future fire events. Results from the Joint Fire Science study are used to display the ability of the model to capture spatial relationships between beetle activity, wildfire, and timber harvest.

An oral presentation will be made.

## INFEST ABSTRACT

### THE FOREST INITIATIVE AND HEALTHY FOREST RESTORATION ACT

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In response to the large wildfires of recent years, in fall of 2002 President Bush released the Healthy Forest Initiative (HFI). This initiative recognized unhealthy forest conditions as a root cause of these destructive fires and the current inability of many land managers to address these issues due to "red tape". The initiative directed the Secretary of Agriculture, the Secretary of the Interior and the Chairman of the Council on Environmental Quality to "improve regulatory processes to ensure more timely decisions, greater efficiency, and better results in reducing the risk of catastrophic wildfires by restoring forest health.

A direct outcome of this initiative is the Healthy Forest Restoration Act that was signed into law on December 2, 2003. This Act contains six primary sections authorizing several of the needed actions identified in the HFI to address the Nation's forest health issues. The stated purposes of the Act are:

- (1) to reduce wildfire risk to communities, municipal water supplies, and other at-risk Federal land through collaborative processes of planning, prioritizing, and implementing hazardous fuel reduction projects;
- (2) to authorize grant programs to improve the commercial value of forest biomass (that otherwise contributes to the risk of catastrophic fire or insect or disease infestation) for producing electric energy, useful heat, transportation fuel, and petroleum-based product substitutes, and for other commercial purposes;
- (3) to enhance efforts to protect watershed and address threats to forest and rangeland health, including catastrophic wildfire, across the landscape;
- (4) to promote systematic gathering of information to address the impact of insect and disease infestations and other damaging agents on forest and rangeland health;
- (5) to improve the capacity to detect insect and disease infestations at an early stage, particularly with respect to hardwood forests; and
- (6) to protect, restore, and enhance forest ecosystem components—
  - (A) to promote the recovery of threatened and endangered species;
  - (B) to improve biological diversity; and
  - (C) to enhance productivity and carbon sequestration.

The Healthy Forest Initiative and Healthy Forest Restoration Act provide new opportunities to address the legacy, millions of acres of dead or highly impacted spruce forests, of the extensive 1990's spruce beetle outbreak in Alaska.

This is an Oral Presentation.



**Performance of planted white spruce under various levels of cover  
in interior and southcentral Alaska.**

**By**

*Michael Newton and Elizabeth. Cole*

*Oregon State University Department of Forest Science, and*

*Andrew Youngblood, USDA Forest Service*

*PNW Forest Research Station, LaGrande, OR*

Information has been gathered in the past 17 years to determine practical limitations on white spruce regeneration in bark beetle-prone forests of interior and southcentral Alaska. Experiments to determine competitive effects of early successional vegetation have shown that cover and overtopping by competing vegetation caused significant reductions in planted seedling growth. Effects were greater on small containerized seedlings than on large transplants; complete control of competing cover gave much greater seedling growth response than when competing cover was reduced by half. Control of competing cover was best provided with good site preparation. Numerous tests of chemicals demonstrated that several were good for site preparation, most particularly glyphosate, hexazinone and occasionally imazapyr. These products, and also triclopyr, dissipated in northern summers much as they do further south, and negligible residues were found a year after application. Glyphosate and imazapyr are virtually immobile in soil, and degrade quickly in forage. Site preparation with a bulldozer displaced some soil; we did not measure erosion, and did not observe evidence of soil loss apart from displacement. Where grass roots remained after treatment, grass cover developed rapidly. Light-seeded birch and alder also tended to invade. In places where soil was especially cold, generally on units with several years accumulation of cover and its detritus, scarification provided slightly warmer soil. Seedling growth after scarification at some sites, however, was no different from that with no site preparation. Chemical site preparation with a mixture of glyphosate and hexazinone provided more consistent improvement in seedling growth compared to scarification and control, but on two of eight installations, seedling growth (seven years after planting) in scarified plots was greater than in other treatments. Trees maintained high growth rates for 12-13 years after planting when removal of nearly all plant competition with annual treatments of glyphosate occurred for the first five years. Whether this level of weeding is economically justified is doubtful. In general, planting before competing vegetation developed after harvesting green or bark beetle-killed forests led to better seedling growth than where regeneration was delayed for a few years. One option for achieving successful seedling establishment when plant competition is not controlled is planting very large stock, provided the site is not already dominated by dense grass or woody vegetation. Even the largest seedlings are slowed by heavy cover or overtopping.

## SPRUCE BEETLE IN THE ROCKIES – CURRENT STATUS AND MANAGEMENT PRACTICES

A. Steve Munson<sup>\*1</sup>, Joel McMillin<sup>2</sup>, Robert Cain<sup>3</sup>, and Kurt Allen<sup>4</sup>

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In the Rocky Mountain area of the western United States, spruce beetle (*Dendroctonus rufipennis*) populations have increased significantly since the mid to late 1990's. From 1990-2002, approximately 1.2 million acres of Engelmann spruce (*Picea engelmannii*) have been affected by this insect. In 2003, spruce beetle populations have increased significantly in Arizona, Colorado and Wyoming. The heaviest mortality has occurred in Utah where spruce beetle activity has been evident since the mid 1980's. In Utah, spruce mortality exceeds 80 percent over 225,000 acres. Spruce beetle caused tree mortality has affected 49 percent of the spruce resource within the state.

Many of the outbreaks have been associated with scattered windthrown trees or clumps of trees that occur within susceptible landscapes. Most of these spruce beetle susceptible landscapes are composed of spruce stands comprised of older trees (175-225 years), stand densities that exceed 160 ft<sup>2</sup> feet of basal area and tree diameters exceeding 10 inches. A variety of management scenarios have been used as prevention and suppression strategies to address spruce beetle activity. Thinning practices have been employed before and during outbreaks to mitigate spruce beetle effects. The success or failure associated with thinning projects depends on treatment objectives, population pressure, and landscape susceptibility. Thinning strategies implemented to protect large diameter spruce in outbreak areas have not been successful.

Suppression tactics have been successful if employed early in the process of a building spruce beetle population and most or all of the affected area is treated. Examples of suppression treatments include trap trees (standing baited or down trees), funnel traps baited with a spruce beetle attractant, sanitation, peeling, burning and lethal trap tree insecticide treatments. Generally, several suppression tactics are used in combination to address spruce beetle populations.

Single-tree insecticide treatments have been used extensively to protect high-value trees. Applied properly, these treatments have been very successful. Most of the failures associated with insecticide treatments are related to applicator error. Flowable formulations of carbaryl provide two-years of protection. Pyrethroid formulations are currently being tested to determine their effectiveness.

In some situations, MCH (3-methyl-2-cyclohexen-1-one) an antiaggregation pheromone has been used to reduce spruce beetle attacks on high-value trees. However, unpublished field trials indicate that MCH is not an effective treatment for outbreak populations of the insect. It may have a limited effect at lower population thresholds. Field tests of the aggregation pheromones in Utah demonstrate that the 3-component lure (frontalin,  $\alpha$ -pinene, &MCOL) is a more effective attractant than the 2-component lure (frontalin,  $\alpha$ -pinene).

## MANAGING INFESTED FORESTS ON STATE LANDS

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The spruce beetle, *Dendroctonus rufipennis* (Kirby), exploded to epidemic levels in white/Lutz spruce stands on state lands throughout southcentral Alaska from 1989 to the present, peaking at over 1.13 million acres in 1996. Over the last two decades, over 4 million acres have been impacted. Spruce mortality in many stands is over 80 to 90 percent. The Alaska Division of Forestry has responded by hiring an entomologist, collaborating with other agencies and communities to address fuel hazards, assisting in cooperative research efforts, providing assistance to small private landowners in response to the infestation, instituted additional wildfire preparedness actions, and initiated an aggressive timber salvage and reforestation program

## EVALUATION OF FIRE RISKS AND HAZARDS

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The spread of the spruce bark beetle (*Dendroctonus rufipennis*) in southcentral Alaska and the resulting effects on wildland fire behavior have been studied for over a decade. The science of fire behavior is evolving with the development of a number of new tools to help fire behavior analysts predict fire spread and intensity. These new tools, coupled with research data collected from spruce bark beetle (*Dendroctonus rufipennis*) infested stands and fire behavior case studies from recent fires, can be analyzed to help land managers prioritize mitigation measures. Geographic information systems (GIS) play a key role in analyzing and presenting data and have significantly improved Alaska's position for a share of the hazard mitigation funding allocated to treat fuels emerging in close proximity to urban areas in the U.S.

Now that managers have made initial assessments of hazard and risk to direct mitigation efforts, there is a need to identify future data collection needs throughout areas in Alaska impacted by the spruce bark beetle (*Dendroctonus rufipennis*). One overlooked data need is weather. More intensive weather monitoring is necessary to track fire danger conditions and provide a tool for fire and land managers to plan ahead. Efforts to re-inventory stands and study the impacts of the spruce bark beetle (*Dendroctonus rufipennis*) must continue. Custom fuel model development, especially for fuel types that reflect the effects of climate change, insect and disease outbreaks and other changes should be prioritized. We are just beginning to understand the evolution of our white spruce (*Picea glauca*) forests and the dynamic wildland fire/fuel conditions emerging after this significant forest health-altering event.

oral presentation

## Climate change and boreal forests

Glenn Patrick Juday

The Arctic Climatic Impact Assessment (ACIA) has provided the opportunity to conduct a circumpolar investigation and synthesis of climate warming and the boreal forest including (1) the record of recent climate change, (2) the vulnerability of forest systems to warming, and (3) scenarios of possible climate change effects from 5 global circulation climate (GCM) models. A specific pattern of climate variability in Alaska is the signal that causes infrequent white spruce cone crops to be produced so that the seeds have the maximum probability of being released into landscapes where fire has recently occurred. A comprehensive view of the record of boreal forest growth in relation to climate contains apparently contradictory records of opposite temperature trends in different parts of the global boreal forest. The opposite growth trends actually can be explained as a result of an interconnected atmospheric circulation system with coupled regional departures that are opposite in their temperature effects. The northernmost boreal forest also offers a unique very long record (up to 6000 years) of very high resolution that provides important perspective when examining current climate warming effects. For example, distribution of trees (sparse stands or individuals) extended all the way to the Arctic shore across the entire Russian Arctic during much of the early Holocene as indicated by frozen wood remains in permafrost. Finally, the varied social context is another crucial factor in examining climate-warming effects on forest systems. In Iceland climate warming is producing a more favorable environment for a large-scale afforestation program, in the Nordic countries investments in forest management are at risk, and in much of Siberia, Alaska, and Canada biodiversity resources are the main focus of concern. A substantial amount of new science supports assessments of the effect of climate warming including the Flakaliden direct warming experiment in Sweden, the IGBP Central Siberian Transect, the BOREAS project in central Canada, and the LTER program and dendrochronological studies in Alaska. Many tree species in different parts of the northern boreal region display a positive growth response to growing season warmth. Generally these are the more humid parts of the boreal forest in eastern Canada and northern Europe. The Central Siberia transect captures a suite of growth responses across a very large latitudinal gradient, and includes trees and sites with negative responses to warmth because of drought limitations. Strong warming in Alaska has been associated with substantial growth reductions on moisture-limited sites, which are widespread in lowlands. Scenarios of 5 GCMs run through the 21<sup>st</sup> century have been calibrated to empirical temperature-tree growth relationships. The scenarios produce climates that would be suitable for substantial increases in individual tree growth in positive-responding tree populations, such as the Tamyir Peninsula and northern Labrador. Warming scenarios also are associated with temperatures that, based on empirical relationships, would not be suitable for the survival of white spruce and black spruce on many site types in Alaska within several decades. Finally, warmth is a critical factor in triggering major agents of change in boreal forests, especially fire and insect outbreaks.

## ANCHORAGE WILDFIRE: VEGETATION TREATMENTS AND ASSOCIATED CONSIDERATIONS TO IMPROVE SURVIVAL AND RESPONSE

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Considering the nature of the boreal forest type and the expanded impact of the spruce bark beetle (*Dendroctonus rufipennis*), wildfire within urban areas becomes an increasing threat to residents and infrastructure throughout Southcentral Alaska. Additionally, this issue has forced residents and agency personnel, alike, to evaluate the influence that personal items and building construction materials incur upon home ignitions. Beyond the immediate area surrounding a home, external factors weigh into fire suppression and response, resident safety, and fire management when preparing a community for survival of a catastrophic wildfire event.

To date, local experience with wildland fire and consideration for forest types, topography, and related potential fire behavior have been used to prioritize fuel treatment projects. Through the evolution of the Municipality's wildfire assessment map, an objective measure combined with logistical considerations will be used to determine prioritization of all future project work, beginning in the 2004 wildfire season.

With the intent of reducing fire spread and intensity, many fuel treatment projects have been implemented to modify the forest stand structure near homes, entire subdivisions, and road rights-of-way. By referencing the fire behavior prediction model BEHAVE in combination with micro and macro influences on structural ignition potential, forested stands are treated to enhance forest health, reduce further beetle activity, and contain wildfires at the surface level.

It is imperative to maintain a forest stand structure that continues to provide for reduced fire behavior while supporting local aesthetic values. These conditions must always be balanced with habitat needs for birds and animals, riparian protection, and soil stability.

PAPER

## A CHANGING ALASKAN FOREST ECOSYSTEM

### ABSTRACT SUBMITTAL BY WADE W. WAHRENBOCK

#### **THE SALVAGE LOGGING EXPERIENCE ON THE KENAI PENINSULA; THE GOOD, THE BAD AND THE UGLY**

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During the 1990's, a bark beetle infestation (*Dendroctonus rufipennis* (Kirby)) occurred on the Kenai Peninsula lowlands. The most intensively impacted areas were from Kasilof to Homer. Mortality of commercial size spruce ranged from 95% to 100% in this zone. As response to this insect epidemic, large and small landowners conducted salvage timber harvest to remove dead forest material. Commercial salvage logging operations were subject to the Alaska Forest Resources and Practices Act. This oral presentation will provide a summary of the commercial harvest trends and the salvage logging experience in response to this forest insect infestation.

## CAN KENAI PENINSULA SPRUCE RESIST BEETLE ATTACK?

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One interesting aspect of Alaska's recent spruce beetle infestation is the variability in spruce tree mortality between different geographic areas of the infestation. In some parts of the Kenai Peninsula, for example, about half the trees were killed, while in other areas, mortality approached 100 percent. The reasons for this variability have been the subject of much speculation. Though a variety of factors is likely involved, we believe that genetically-based differences in the ability of these trees to resist attack play a critical role.

In the 1980s, one of us (Alden) collected seed from spruce trees at 40 locations on the Kenai, from stands not yet impacted by this infestation. In 1998, we returned to those same stands and searched for healthy trees. In many cases, there were none; spruce beetles had killed or infested every tree in the stand. But we were able to collect seed from uninfested or lightly infested trees at 27 of the original 1980s collection sites, including collections from the areas of Summit Lake, Cooper Landing, Snug Harbor, Tustumena Lake and East Homer Road. Collection trees were marked and their locations recorded, but because they are scattered over the Peninsula on land of a variety of ownerships, their future is uncertain.

Seedlings grown from both collections were outplanted in 2000 near Clam Gulch. In our experiment, seedlings grown from seed collected in the 1980s will function as our "control" group. The level of resistance to beetle attack in this group should be no different than the overall pre-infestation population. Seedlings grown from seed collected in 1998 will function as our "presumed resistant" group. By virtue of the survival of their parent trees to 1998, we hypothesize that this group has some genetically-based ability to resist beetle attack. The plantations preserve the two genomes for a variety of types of future experimentation.

# MANAGING ALASKA'S SPRUCE BEETLE-IMPACTED FORESTS: EFFECTS ON NITROGEN AVAILABILITY AND FOREST REGENERATION

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We investigated management approaches associated with an extensive outbreak of spruce bark beetle (*Dendroctonus rufipennis* Kirby) by attempting to quantify ecosystem effects within five different forest management treatments of beetle-impacted stands. On the Kenai Peninsula, we examined effects of high intensity burning, whole tree harvest, whole tree harvest with nitrogen (N) fertilization and selective harvest of beetle-impacted forests four years after treatment. In the Copper Basin, we examined ecosystem effects of clear-cut salvage logging of beetle-impacted forests six years following harvest. We measured available soil nitrate and ammonium and potential N loss from leaching using *in situ* cation and anion resin exchange capsules. We also assessed spruce tree regeneration and conducted extensive biomass surveys to estimate understory response.

Availability and losses of N did not differ among any of the management treatments. Even a substantial application of N fertilizer had no long term effects on N availability. Spruce regeneration significantly increased after high-intensity prescribed burning, with 73 times more seedlings/m<sup>2</sup> in burn plots than in plots that did not receive treatment. Biomass of the pervasive Canada Blue-joint grass (*Calamagrostis canadensis* [Michx.] Beaux.) was significantly reduced by burning, with burn plots having 9.5% of the *C. canadensis* biomass of plots that did not receive treatment. *C. canadensis* biomass was over twice as great in N fertilized plots than in plots with no treatment. Clearcut salvage logging in the Copper Basin caused a dramatic reduction in the percent cover of moss, and increased the cover of several early successional species.



## SOCIO-ECONOMIC IMPACTS OF THE SPRUCE BARK BEETLE ON THE KENAI PENINSULA: THROUGH COMMUNITY VOICES

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The spruce bark beetle's dramatic affect on the Kenai Peninsula has resulted in substantial variation in response from communities situated within this dynamic landscape. Key informant interviews conducted in six Kenai Peninsula communities during the summer of 2003 reveal differences in the perception of biophysical and socio-economic impacts and risks from changes in forest conditions. These interviews provide evidence of collective experience and community risk perception across Kenai Peninsula communities.

Fire, falling trees, watershed quality, wildlife habitat, economic fluctuations, changing aesthetics, and quality of life are some of the issues faced. In some communities, positive economic change brought by an increase in timber harvesting in the wake of the spruce bark beetle is perceived as equal or paramount to negative perceptions of the changing landscape. In other communities, the loss of a living spruce forest has profoundly affected quality of life, and has also led to community conflict, increased risk perception, and economic challenges. Communities at different stages in the spruce bark beetle outbreak show that perceived impacts vary across time as well as space. Differences in the array of perceived impacts from the spruce bark beetle outbreak in Kenai Peninsula communities present opportunities and obstacles for forest management in the context of changing forest conditions. Lessons learned from this experience may be extrapolated to other contexts of natural resource disturbance and change.

## **SAWMILLS, KILNS AND MILLIONS OF TREES: THE SALVATION AND/OR CREATION OF A VALUE ADDED WOOD INDUSTRY IN SC ALASKA**

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Having worked with the forest products industry in Alaska for over sixteen years, I have seen many changes to the size and structure of this industry. Some of these changes, new equipment and more modern procedures, have resulted in great improvements in both better manufactured products for the market and finding new and better uses with higher values with greater returns to the industry. Unfortunately, there have been some changes that did not give the forest products industry a chance to fill a lot of the market needs. A sufficient supply of quality timber so that an industry could prove to a financial lender that the industry was a good prospect as an investment in more modern equipment and procedures is probably the a main reason why the industry has not been able to meet the needs of the market.

Spruce trees that have been killed by the bark beetle have been harvested in large volumes and have found markets for both solid wood products and as chips. This was a large market for over ten years, but the quality and quantity of spruce logs that are currently available limit the opportunities on the Kenai Peninsula. The markets that are possible for spruce logs that come from beetle killed trees has been changes to many fewer and lower valued products. If a tree was killed 10 years ago, the market most probably be in a form of bio-fuels for energy or products produced from the chemicals of the wood. As a solid product, sawn, turned, or scribed logs for house log construction should remain a market for several more years as long as the logs that are used where structural strength is important have few deep checks and limited spiral grain.

New growth spruce trees that may be smaller diameter but are harvested from live trees will have limited markets for many different products that are being developed by industry and research. Trees that are 6 to 10 inched in diameter at the stump will fit into this category.

## Product Opportunities for Deteriorating Beetle-Killed Spruce

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Information on deterioration rates and product opportunity is important in determining salvage potential of timber damaged or killed by the spruce bark beetle (*Dendroctonus rufipennis* (Kirby)). A substantial volume of spruce timber from trees killed by the spruce bark beetle is available on the Kenai Peninsula, Alaska. Lands managed by the Forest Service, the State of Alaska, the Kenai Peninsula Borough, and private owners are all affected. The product utilization timeline is relatively short for recovering traditional or some higher-value products. Foresters, entomologists, and researchers prepared a four-level, visual classification system based on tree condition prior to selecting a sample of trees for a product recovery study. This classification system was used to evaluate the effects of beetle caused deterioration over time on the volume and value recovery for several products. Products considered were lumber, veneer, house logs, and pulp.

Results indicate that for lumber and veneer, only 2 deterioration classes are needed to adequately determine volume and value loss in beetle-killed and beetle-infested spruce on the Kenai Peninsula. Inherent defect in the spruce resource combined with the beetle damage limits product opportunity. Lumber and veneer volume and quality declines rapidly following death of a tree. Pulp quality was not affected but no tests were done on pulp yield. There exists a high potential for use of dead spruce in log homes, should the manufacturing infrastructure exist and market conditions be favorable. Additional research on use of dead spruce as a raw material source for composite or engineered wood products would be beneficial in identifying value-added product potential.